Ocean Engineering 38 (2011) 1291–1299

Contents lists available at ScienceDirect

Ocean Engineering

journal homepage: www.elsevier.com/locate/oceaneng

Manoeuvring prediction of pusher barge in deep and shallow water

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ARTICLE INFO

Article history:
Received 16 November 2009
Received in revised form
27 October 2010
Accepted 15 May 2011
Editor-in-Chief: A.I. Incecik
Available online 25 June 2011

Keywords:
Pusher barge
Turning circle
Zig-Zag manoeuvring
Shallow water
Deep water

ABSTRACT

This paper presents an experimental investigation on the manoeuvring characteristics of a pusher-barge system for deep ($H/d>3$) and shallow water ($H/d=1.3$) condition. Since, the operation of pusher-barge mainly concentrates on confined waters, there is a need to predict and analyze the manoeuvring characteristic of the system for a safe and acceptable performance. A time domain simulation programme was developed for this purpose. A series of model experiments were carried out to determine the hydrodynamic coefficients using a planar motion mechanism (PMM). The time domain simulation shows the manoeuvring characteristic in the form of turning circle trajectories and zig-zag manoeuvre based on the hydrodynamic coefficients, which were derived based on experimental results. The manoeuvring characteristics in shallow and deep water conditions were compared through the simulation results. A comparison of simulation results based on experimental and empirical driven coefficients for both conditions shows that the experimental coefficients gave better manoeuvring characteristics for both turning circle trajectories and zig-zag manoeuvre.

1. Introduction

Presently, the most economical means of carrying goods in inland waterways for Indonesia and Malaysia is through barges. However, the use of barges in towing mode could affect its safety, as it has to manoeuvre in rivers of confined waters. In order to enhance safety there is growing use of pusher-barge systems for carriage of cargoes, which is an alternative mode of transportation in inland waterways and coastal regions that offered a minimum operating cost and safety. This system must have good manoeuvring capabilities to maintain its intended course in inland waterways, coastal area and in ports. The pusher barge must also be able to stop within a reasonable distance or turn within the reasonable turning path in order to avoid some hazardous conditions, such as collision, ramming and grounding.

Manoeuvring characteristic of a pusher barge is dependent on the parameters of the waterways such as bank shape and water depth (Lataire et al., 2007). Vantorre and Eloot (1996) compared different formulations of lateral force and yawing moment with model experiment results for shallow water manoeuvring for all drift angles and found that a tubular formulation of the lateral force and the yawing moment was needed to cover the whole range of drift angles. According to Beukelman and Journee (2001), deduction of water depth causes an increase of moment and lateral force, which will reduce the manoeuvring capability of a vessel.

Since steering and manoeuvring describes the pusher barge motions on a horizontal plane, atime domain coupled equation may be developed to describe the motions. The coefficients of the various terms in the equation are referred to as the hydrodynamic derivatives. These derivatives are dependent upon the hydrodynamic flow around the ship hull, which in turn depends on the geometry of the submerged body of the hull (Wang et al., 2000). This research focuses on a simulation programme, which was developed based on the hydrodynamic coefficients to predict the manoeuvrability of the pusher barge.

2. Mathematical model

The mathematical model for manoeuvring motion can be described by the following equation of motion, using the coordinate system in Fig. 1.

$$X=\tfrac{1}{2}\rho L^2 d(m'+m_x')\dot{u}-\tfrac{1}{2}\rho L^2 d(m'+m_y')rv$$

$$Y=\tfrac{1}{2}\rho L^2 d(m'+m_y')\dot{v}+\tfrac{1}{2}\rho L^2 d(m'+m_x')ru \quad (1)$$

$$N=\tfrac{1}{2}\rho L^4 d(I_{zz}'+J_{zz}')\dot{r}$$

where m, m_x, and m_y are the mass of ship, and added mass in x- and y-directions, respectively; I_{ZZ} and J_{zz} moment of inertia and add moment of inertia around z-axis, respectively; β is Drift angle at the centre of gravity C.G. [$\beta=-\sin^{-1}(v/U)$]; r' is dimensionless turning rate [$r'=r(L/U)$]; r and v are the turning rate and sway

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doi:10.1016/j.oceaneng.2011.05.011